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Twenty-Four Hour Post-Exercise Hypotension Following Concurrent Cardiovascular and Resistance Exercise

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TWENTY-FOUR HOUR POST-EXERCISE HYPOTENSION FOLLOWING CONCURRENT CARDIOVASCULAR AND RESISTANCE EXERCISE

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24-HOUR POST-EXERCISE HYPOTENSION FOLLOWING CONCURRENT CARDIOVASCULAR AND RESISTANCE EXERCISE

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Despite pharmacological advances, exercise remains a cost effective preventative for cardiovascular disease (CVD) by acutely and chronically lowering systolic blood pressure (SBP). Although numerous studies have investigated aerobic and resistance training's role in eliciting an acute SBP response termed post-exercise hypotension (PEH), few researchers have investigated how performing both cardiovascular and weight training in a single session (concurrent training) or how different prescriptions for order of exercise modality will elicit this PEH response; no known studies have attempted altering the order of exercise types within each session. This study seeks to determine if the order of exercise type will affect a PEH response following concurrent exercise. Participants (n=13), considered low risk for cardiovascular disease participated in a control session, graded exercise test (GXT) and two concurrent sessions, with concurrent sessions counterbalanced for order of exercise mode. Recovery SBP was analyzed in the laboratory for sixty minutes and for twenty-four hours thereafter using an ambulatory blood pressure monitor. All exercise conditions elicited a depression in SBP; however, only the cardiovascular-weight training (CVWT) concurrent session elicited PEH (p = 0.05). However, there were no differences in SBP attenuation between conditions. There was no main effect for PEH between conditions during twenty-four hour assessment. With no statistically significant differences in the magnitude of PEH twenty-four hours after exercise, it may be determined that the order of exercise does not

affect the preventative attributes of aerobic and resistance exercise in regards to acute SBP response. Furthermore, only exercise involving resistance training (CVWT) provoked PEH during the first 60 minutes; therefore it may be argued that individuals should pair cardiovascular exercise with weight training in order to elicit the greatest cardiovascular benefits. Future studies should consider evaluating the effect of time of day and PEH following concurrent exercise to determine if pairing exercise modalities will at different times will affect the blood pressure response.

CHAPTER 1

INTRODUCTION

Hypertension (HTN) is a major public health concern, affecting 28.7% of the American population [1]. Defined as a chronically elevated systolic blood pressure (SBP) of $\geq$ 140mmHg and/or a diastolic BP of $\geq$ 90mmHg, HTN costs effected Americans $1,500 annually in medical care [1, 2]. Despite vast technological and pharmaceutical breakthroughs in the treatment of HTN, the value of exercise remains due to the minimal monetary costs and side effects associated with lifestyle changes [1]. For this reason, major health organizations recommend physical activity as a preventative and treatment for HTN [1]. Physical activity lowers systolic BP both acutely and chronically; this acute response following a bout of exercise or activity is termed post-exercise hypotension (PEH).

The occurrence of PEH has been reported in various modalities of exercise, i.e. cardiovascular, resistance and concurrent exercise (CE). Concurrent exercise is the pairing of aerobic and resistance exercise in a single exercise session. Despite the reports of PEH in various modalities of activity [3, 4], cardiovascular exercise is predominantly prescribed for those in need of chronic blood pressure maintenance. Numerous studies have validated the PEH response following cardiovascular and resistance exercise, yet very few have investigated the role of pairing the two [4, 5]. The value in pairing the two exercise types may lie in simultaneously obtaining both cardiovascular and musculoskeletal gains.

Statement of Problem and Purpose

To date, concurrent literature investigating PEH is limited to two known investigations; these studies measured PEH for 120 minutes post concurrent exercise [4, 5]. Furthermore, these investigations did not consider changing the order of exercise to determine if vasoconstriction associated with resistance exercise would negatively affect the blood pressure response if performed after an aerobic session [4, 5]. At this time, there are no known studies that have determined the role of exercise order in concurrent exercise or measured PEH for twenty-four hours following concurrent training. Therefore, the purpose of this investigation was to evaluate twenty-four hour PEH following a bout of cardiovascular/weight training concurrent exercise (CVWT) and weight training/cardiovascular concurrent exercise (WTCV).

Statement of Hypotheses

It was hypothesized that there would be no differences between WTCV and CVWT exercise sessions in regards to twenty-four hour PEH (H_{O1}). It was conjectured that WTCV would not see similar magnitudes of twenty-four hour PEH when compared to CVWT (H_{A1}). It was also postulated that there will be no difference between concurrent sessions and a single bout of maximal aerobic or a no exercise control session in regards to twenty-four hour PEH (H_{O2}). It was posited that concurrent exercise sessions would elicit a greater reduction in twenty-four hour PEH when compared to a single bout of maximal aerobic or a no exercise control session (H_{A2}).

Limitations

Limitations to this study include:

Recruitment and attrition of participants

Recruitment of non-smokers

Participants removing ambulatory blood pressure monitor during sleeping hours

Variability in stressors influencing participants' labile measurements

Delimitations

Delimitations include:

Participants: males and females, 18-44 years old

Participants were non-smokers, free from any cardiovascular, pulmonary or metabolic diseases

Participants were stratified as "low risk" for cardiovascular disease [2]

Participants successfully completed maximal musculoskeletal and cardiopulmonary testing

Definition of Terms

- Accelerometer: portable device designed to measure the energy expenditure of daily living
- AE – Aerobic exercise
- Ambulatory blood pressure monitor (ABPM): the mechanical monitor that measures resting blood pressure

- Blood pressure (BP): the pressure exerted by the blood on the wall of the arteries; measures are in millimeters of mercury (mm Hg) [5]
- CE – Concurrent exercise: the combination of aerobic and resistance exercise in one training session
- Diurnal variation: variations that occur throughout the day [6]
- CVD—Cardiovascular Disease
- CVWT – Cardiovascular exercise followed by weight training in a single session
- Hypertension (HTN): a condition in which the blood pressure is chronically elevated above optimal levels [5]
- PEH – Post Exercise Hypotension. PEH is a cardiovascular response to exercise or activity that acutely attenuates systolic and/or diastolic blood pressures.
- RE—Resistance exercise
- WTCV- weight training followed by cardiovascular exercise in one session

CHAPTER 2

REVIEW OF LITERATURE

Introduction

Hypertension (HTN) is a major public health crisis affecting 58.4 million Americans [1]. Although pharmaceuticals are successful in lowering blood pressure (BP), these medications are often accompanied by unpleasant or potentially dangerous side effects. As an alternative to medication, regular physical exercise has shown to be an effective tool in lowering BP with minimal costs or side-effects [1, 6]. The acute lowering of the BP response following exercise has been termed post-exercise hypotension (PEH); this PEH response has been reported for up to twenty-two hours following aerobic exercise [7]. Resistance and concurrent exercise have shown similar reductions in PEH responses [3-5, 8-10]. The specific mechanisms that elicit PEH remain unclear, but there seems to be little variations in BP responses between heterogeneous populations [8, 11-13]. While numerous studies have evaluated the PEH response following various exercise intensities and durations with aerobic and resistance exercise, few have been conducted to determine PEH in concurrent exercise [4, 5, 10, 12, 14-26]. This review will serve to provide information concerning hypothesized mechanisms responsible for PEH and how time of day, disease state, and exercise mode may affect PEH.

Post-exercise hypotension

Internal Mechanisms

Post-exercise hypotension refers to the acute drop in systemic vascular resistance following exercise that is not completely matched by increases in cardiac output [27]. While the specific mechanisms behind PEH remain unknown, it is hypothesized that the decrease in resting heart rate and circulating catecholamines after training may play a part in the PEH phenomenon. Compounding this response, a decline in sympathetic nerve activity results in cardiac output values diminishing faster than systemic vascular resistance can recover [27]. The imbalance between cardiac output and systemic vascular resistance may be responsible for hypotension following exercise [27]. Exercise criteria responsible for the magnitude and duration of this decrement are currently undefined [26].

External mechanisms

Numerous factors external to cardiac output and total peripheral resistance may affect PEH; currently under investigation, diurnal variation, caffeine, training status, sex and cardiovascular disease state are being considered as variables with potential to mediate PEH. One investigation produced evidence that the decreased peripheral pressure associated with PEH was found outside of the localized exercising tissues, potentially indicating that hypotension is a whole body event [26]. If hypotension is truly a full body response to exercise, it is only reasonable that factors responsible for inducing some sort of full body reaction may also play a role in PEH.

Most arguably, the greatest potential mediating factor for PEH is an individual's inherent BP. Essential hypertension is considered a common disease that results from a mutuality of multiple genetic and environmental determinants [28]. There appears to be a genetic linkage between angiotension and hypertension; cross sectional investigations have found links between hypertension and molecular variants of angiotension which may represent an inherent disposition to essential hypertension [28]. The diseased state of HTN is comprised of multiple delineating categories: Normotensive (<120/80mmHg), Stage I hypertensive (130-159/90-99mmHg), and Stage II hypertensive (≥160/100) [29]. Currently there exists a gap in PEH literature involving the impact of PEH on the prevention and rehabilitation of various cardiovascular disease states such as: HTN, chronic heart failure, and heart disease, etc. Studies investigating PEH in hypertensive participants found greater magnitudes of PEH when compared to age matched normotensive individuals [8, 12, 20, 30-33].

On occasion, men and women demonstrate varied physiological adaptations to exercise, thus necessitating individualized exercise prescriptions [6]. As heart size, functional ability and efficiency often vary according to sex, it may be hypothesized that PEH may be altered by this variability cardiac responses. Conversely to this hypothesis, numerous studies investigating both sexes found no significant variability in PEH response between genders [13, 14, 34-39]. In one investigation, despite not finding differences in PEH response, the author reported variability in the mechanisms responsible for PEH between sexes [11]. Interestingly, Senitko (2002) found that sedentary men, women and active women demonstrated PEH as a result of arterial vasodilation, however, trained men elicited the response as a result of a reduction in cardiac output with no change in total peripheral resistance [11]. Despite the mechanical variability reported by Senitko [11], studies have failed to produce significant PEH variability between sexes with similar resting blood pressures.

Ergogenic aids are designed to alter bodily functions in order to produce a desired result. Caffeine is a well-known aid designed to heighten alertness, motor performance and sensory activity through cardiovascular stimulation [40]. While a plethora of investigations have serviced caffeine's effect on resting BP, few have looked into caffeine's effects on PEH. One study presented data suggesting that the ingestion of caffeine, equivalent to two cups of coffee, would successfully inhibit a PEH response [41]. This data is evidence enough to restrict the consumption of caffeinated products in PEH research participants in the current investigation.

Diurnal variation is the product of neuroendocrine mechanisms that are directly affected by physical, mental and pathologic stimuli; as such, these stimuli may activate or inhibit the biological rhythmicity that lead to the abnormalities in twenty-four hour BP patterns [42]. These physical, mental and pathologic stimuli affect individuals differently throughout the day, leading to the variability in blood pressure patterns. Diurnal variation simply means physiological variations the body undergoes throughout the day. According to literature at hand, blood pressure rises sharply after waking, falls slightly in the early afternoon and rises again in the early evening [43]. With inconsistent BP in ambulatory conditions, investigations have been conducted to determine if PEH is affected by this variability. Researchers have reported that an individual may see a greater change in SBP following exercise in the afternoon (4:00pm) compared to early morning (8:00am) [23]. However, the authors also reveal that the individuals typically had higher SBP in the afternoon compared to the morning session, thereby suggesting that the greater degree of change was due to the elevated SBP, rather than the time of day [23]. Park et. al. (2005) evaluated diurnal PEH variability in individuals with hypertension; the authors revealed that those categorized as dippers (those who experience a “dip” in BP while sleeping) were unaffected by the time of exercise prescription, despite their disease state [44]. However, these findings may indicate the importance of performing testing procedures at the same time of day to ensure reliability within each subjects’ data. More studies are needed to further investigate the role of diurnal variation and PEH.

PEH related to Exercise Prescription: modality, duration and intensity

Although there are numerous studies investigating PEH, the results are at times contradictory from variability in the prescription of exercise (modality, duration, intensity). For example, these studies in adults suggest PEH following exercise [4, 5, 7, 10-12, 14, 17, 24, 35, 36, 39, 41, 45-49] whereas these reported no PEH when compared to controls [3, 50, 51]. Despite the majority of studies finding PEH following acute exercise, few considered the effect an individual’s regular exercise routine might have played in their PEH response. When comparing moderately trained to sedentary individuals, researchers have reported no significant differences in PEH response following aerobic or resistance exercise [11, 14], despite the lower resting BP in trained individuals [37]. With the data presented in these studies, it may be accepted that training status does not alter one’s PEH response to aerobic or resistance training.

Despite the research suggesting that regular exercise lowers one’s blood pressure both acutely and chronically, studies exist that may challenge these findings [3]. Besides the conflicting data, there exists a gap in the literature regarding when the onset of chronic BP reduction occurs in individuals who are regularly aerobically or strength training. Neurological adaptations are well defined as the first weeks of commencement of regular resistance training [34], yet there is no known data defining the timeline an individual may expect to experience a similar cardiovascular adaptation. The onset of chronic hypotension following regular exercise needs to be assessed in all modes of training.

Exercise mode

PEH in response to specific exercise modes remains unclear. Investigators have most often evaluated cardiovascular and resistance training in regards to PEH response. Comparing PEH responses the literature is difficult due to a lack of uniformity in duration and intensity of exercise. In this review, the exercise modalities in question are cardiovascular, resistance and concurrent training. Although not currently supported as a preventative measure for HTN by the Joint National Committee, some data exists supporting PEH responses in resistance, aerobic, and concurrent exercise [52]. In these studies investigating PEH following various modes of activity, researchers found variability in the magnitude and duration in the BP response following various exercise prescriptions (altering frequency, intensity, type and time).

As a way to maintain and improve cardiovascular health and offset the long-term deleterious effects of HTN, the American College of Sports Medicine and Joint National convention recommend daily aerobic exercise at moderate to vigorous intensities (ex. 40-85% VO2R) [6, 48]. Rather than prescribing exercise based off of an individual's max VO_2, the American College of Sports Medicine (ACSM) now recommends basing exercise prescription on $VO_{2reserve}$, which defined as the percentage of difference between resting VO_2 and maximum VO_2 [49].

The beneficial role of aerobic exercise on chronic BP is generally accepted, but debates continue on how to best elicit an acute response. Data presented by several investigations suggest longer durations and higher intensities of aerobic exercise produced greater durations and magnitudes of PEH [7, 12, 19, 34, 35, 39, 50] while some saw no significant differences in varying aerobic intensities or durations [14, 53]. Cornelissen et. al. (2010) sought to determine if exercise intensity would elicit a change in PEH responses. Normotensive, trained and untrained individuals cycled at 33% and 66% heart rate reserve (HHR) for 50 minutes; the study presented data suggesting significant PEH following each intensity when compared to a non-exercise control session [14]. Although the study by Cornelissen et. al. (2010) found no difference between exercise intensities, a study by Forjaz et. al. (2004) found significant differences between aerobic exercise at 30%, 50% and 75% VO_{2peak} with the greatest magnitude and duration of PEH following higher intensities [22]. However, Pescatello (2004) presents data suggesting that PEH is a low threshold event; aerobic exercise at 40% VO_{2max} was as effective in attenuating blood pressure as cardiovascular exercise at 60% intensity in hypertensive older men [54]. Evidence from Pescatello et. al., (2004) may insinuate that older populations benefit from lite intensity exercise as a stimulant for PEH while moderate intensity exercise may serve as an antihypertensive therapy for more physically fit men [54]. Despite the findings by Cornelissen et. al. (2010) and Pescatello et. al., (2004), most studies investigating the role of intensity on PEH demonstrates a greater magnitude and duration of PEH following higher intensities of exercise compared to lower intensities.

Resistance training is recommended as a part of regular exercise program and lifestyle modifications to prevent HTN [6, 55]. Due to vasoconstriction associated with resistance training, maximal effort in this modality of exercise may be contraindicated for persons with diagnosed HTN when accompanied by certain comorbid conditions [6]. It is generally recommended that individuals perform submaximal effort (60-70% 1RM) during resistance exercise over a greater number of sets and repetitions in order to maintain musculoskeletal health [6]. It is well established that individuals should train the musculoskeletal system to maintain the ability to perform daily tasks [6], however, the effect weight training has on PEH has only recently been investigated. Researchers have explored the potential role of high [36, 37, 48, 56] and low [36, 45, 46, 48] intensities of musculoskeletal exercise and the role in eliciting PEH. Rezk et. al. (2006) recruited normotensive young adults to assess if higher and lower intensities of resistance training would elicit varying PEH responses [36]. Individuals displayed PEH following 3 sets of 20 repetitions on 6 (upper and lower body) exercises at 40% and 80% 1RM; the greatest magnitude of PEH followed exercise at 80% of 1 RM, but duration of PEH was not different between the intensities [36]. Despite these findings, some authors continue to argue that there is not enough consistent data to recommend resistance training for PEH [3]. In a review by Cardoso et. al. (2010), investigations attempting to define an ambulatory PEH response following resistance exercise are scarce and inconclusive [3]. Cardoso suggests that with the present evidence, only low intensity resistance training should be prescribed to elicit an acute PEH response [3]. However, it is difficult to make a summative assessment on how the circulatory system will respond to this modality when the reviewed manuscripts by Cardoso et. al. (2010) demonstrated investigations prescribing incredibly variable exercise prescriptions (variability in set and rep schemes along with intensity of each session). Despite great efforts to define PEH responses to exercise, it is apparent that inconsistencies exist in the literature regarding PEH following resistance and cardiovascular exercise. Furthermore, there is little to no known data describing effectiveness of conjoining the two exercise modalities into a single exercise session to elicit a greater PEH response.

Concurrent exercise is the pairing of cardiovascular and resistance exercise in a single activity session. The ACSM recommends individuals to not only perform activity to condition the cardiorespiratory system, but to also maintain a loading exercise program that provides resistance for musculoskeletal and bone health [6]. The combination of both training modalities may provide a more holistic training approach for overall body conditioning. Another added benefit to concurrent training is that an individual may exercise at higher intensities in each mode due to different muscle recruitment patterns. Potential issues may arise when concurrently exercising, such as attenuating a PEH response due to resistance training [5] and pre-fatiguing major muscle groups prior to performing resistance exercises [57]. The importance of cardiovascular and musculoskeletal exercise to maintain healthy cardiorespiratory and skeletal systems is well established, but it is unknown as to the impact the combination of these two modes (weight training and cardiovascular) during a single session of exercise may have on magnitude and duration of PEH following an acute bout of training.

PEH and concurrent exercise

Despite the holistic training and health benefits provided in concurrent exercise, few studies have been conducted evaluating PEH following concurrent training. Of the two published studies involving concurrent exercise and PEH, researchers found that PEH occurred following a combined weight training (WT) and cardiovascular (CV)nexercise session.[4, 5]. Normotensive participants exercised at 80% of 1RM for 2 sets of 6-8 repetitions on 6 exercises (leg press, leg extension, leg curl, bench press, lat pull down and shoulder press) with a duration of approximately 30 minutes and then performed 20 minutes on a cycle ergometer at 65% VO_{2peak} (concurrent session lasted approximately 1 hour including rest intervals); significant differences were found between concurrent and the non-exercise control session [5]. It is important to note, participants experienced a similar PEH response following comparable durations of concurrent and aerobic exercise [5]. In another investigation the researchers modified the aerobic exercise protocol in order to determine if higher or lower intensities of aerobic exercise would alter PEH during concurrent WT and CV exercise [4]. Healthy normotensive adults participated in a concurrent exercise protocol requiring 2 sets of 6-8 repetitions on 6 resistance exercises at 80% of 1RM and 20 minutes of aerobic exercise at 50%, 65%, and 80% VO_{2peak} [4]. The results indicated that all exercise protocols elicited PEH, but the greatest magnitude and longest duration ($\geq$ 120 minutes; BP assessment discontinued after 2 hours) of PEH followed higher intensities [4]. If concurrent exercise can produce comparable reductions in BP to that of a single cardiovascular session, individuals may simultaneously acquire musculoskeletal and cardiorespiratory gains with concurrent exercise while experiencing a PEH response similar to aerobic training.

Based on PEH literature, the acute drop in BP following exercise has been reported with various training intensities, durations and modalities, genders and various cardiovascular disease states. Cardiac output and total peripheral resistance are currently the only defined mechanisms to potentially account for PEH, although it is believed that many other physiological components likely play a role in this hypotensive response. Vasodilation associated with regular cardiovascular aerobic exercise leads professionals to recommend this style of exercise as a preventative measure and a treatment for HTN [55]. Not only has cardiovascular exercise been shown to produce a chronic BP effect, this form of training has also shown to create an acute hypotensive response [4, 5, 7, 10, 16, 23, 24, 58, 59]. Despite vasoconstriction adjoined with resistance training, many studies have shown that loading exercises produce PEH at a variety of intensities [5, 9, 13, 45, 56, 60, 61]. The coupling of cardiovascular and resistance exercise in concurrent training may produce comparable reductions in BP to an equivalent bout of aerobic exercise. If concurrent weight training-cardiovascular exercise produces PEH similar to that of aerobic training, concurrent exercise may become a preferred mode of training due to the holistic physiological gains.

Based on the previous literature, it is necessary to continue to provide data on the impact of combining aerobic and resistance training on magnitude and duration of PEH. To date, PEH investigations measuring hypotension following concurrent training recorded BP for only 120 minutes post-exercise, despite reporting below baseline BP values at the end of the testing session [4, 5]. It is necessary to measure the magnitude and duration of PEH for longer durations to better quantify how long PEH will remain following concurrent exercise. Furthermore, protocols in past concurrent studies limited exercise order to resistance exercise followed by aerobic exercise. The rationale behind this particular exercise order was that vasoconstriction associated with resistance training following cardiovascular exercise may attenuate an aerobic PEH response [4]. Although this hypothesis is justifiable, no known data supports this claim. Being that individuals may prefer to perform one exercise type before the other, it is important to determine if the order of exercise will affect the PEH response. By knowing if order of exercise will affect an acute BP response, individuals may prescribe exercise based on which order will elicit the greatest magnitude and duration of PEH.

Conclusion

No known concurrent studies have implemented the measurement of post exercise BP for 24 hours; therefore, the extent of PEH following concurrent training remains unknown. If a difference in magnitude and duration in PEH is found between WTCV and CVWT exercise, professionals will be able to better prescribe exercise to elicit the greatest PEH response possible. This study sought to determine the most appropriate exercise order that produces the greatest magnitude and duration of PEH and measured PEH for twenty-four hours.

CHAPTER 3

METHODOLOGY

Participants

Participants (n=13) were between 18-44 years old, physically active, defined as performing moderate to vigorous activity (aerobic or resistance) a minimum of 30 minutes a day on most days of the week, and stratified as low risk for cardiovascular disease. To validate their activity level, participants qualitatively defined their past and present levels of engagement in physical activity (Appendix E). Participants were free from any cardiovascular, pulmonary or metabolic disorders (Appendix B & C). Participants were unable to participate if suffering from any acute illnesses or orthopedic injuries. Furthermore, participants were excluded if their resting blood pressure met the $\geq$ 140/90mmHg criteria. Volunteers in the study were excluded if they were current smokers or had smoked in the last 6 months.

Participants were recruited from campus bulletin board advertisements, social media and word of mouth. In this within participant study, individuals completed all study protocols based on a counterbalance, with a minimum of 48 hours between sessions. Prior to the commencement of data collection, participants signed an informed consent. All protocols relating to the investigation were approved by Western Kentucky's Institutional Review Board.

Non-exercise assessments

Paperwork and anthropomorphic measures

Each participant's first day was a non-exercise control session. The subsequent four testing sessions were performed according to a random counter-balanced order. On the control day, participants signed the informed consent document (Appendix A) and completed a medical history (Appendix B) and PAR-Q (Appendix B). All study instructions and procedures were thoroughly explained to the participant prior to testing. Height was assessed to the nearest .5cm, facing forward, nose parallel to the ground, with no shoes on a Seca 222 full length stadiometer (Hamburg, Germany). Mass was measured on a Detecto DR400 digital scale (Webb City, MO) to the nearest .1kg, without shoes. Body composition was measured by the same trained technician using a seven site skin fold procedure (Jackson and Pollack) using Lange skin fold calipers (Santa Cruz, CA) [6].

Blood pressure assessment

A successfully validated ambulatory blood pressure monitor (ABPM), the SunTech Medical Oscar 2 device (SunTech Medical, Morrisville, NC, US) was declared to be sound according to International Protocol for the validation of blood pressure monitoring devices [62]. Blood pressure was taken assessed using the Oscar 2 ambulatory blood pressure monitor to ensure reliability of BP measurements throughout the twenty-four hour period. Resting BP was taken two times, at 10 minute and 15 minutes; the control session served as a means to validate the resting BP measurement intervals by analyzing any potential variation in BP throughout one hour. During this phase, participants sat upright with their feet flat on the floor with the back supported. Participants sat for a total of 60 minutes while the ABPM assessed BP every five minutes.

In order to effectively measure twenty-four hour BP, researchers utilized the same ambulatory blood pressure techniques used to measure resting BP. The data collected from this device was accepted as valid and reliable in adult populations. Participants were given standard instructions for the blood pressure protocol when wearing the ABPM. Participants wore the ABPM after every testing session for twenty-four hours with the exclusion of the time while asleep. A blood pressure cuff was fitted to the participant's non-dominant arm and the ABPM was fastened to his or her waist using a belt. The participants were asked to continue normal activities of daily life with the exclusion of planned exercise. Activities of daily living were not regulated or controlled for, allowing the data to be generalizable.

Non-exercise control session

A graphical depiction of the study design is available in Appendix F, Table 1. All individuals' Day 1 served as a non-exercise control session along with briefing the participant on testing procedures, and the completion of study paperwork. Participants' initial resting blood pressure and heart rate was analyzed after 10 minutes of seated rest and the second measurement 5 minutes after the first. Blood pressure was assessed by the guidelines mentioned above. In order to control for one hour of post exercise activity, participants remained in the Exercise Physiology lab for 60 minutes following every testing protocol for BP assessment. Blood pressure was assessed every five minutes using the Oscar 2 ABPM. This technique of blood pressure assessment in the laboratory allowed the participant to become fully acquainted with the device before leaving the researcher.

Graded exercise test

Participants performed a graded exercise test (GXT) on a treadmill using the Bruce protocol [63]. Gas analysis was measured using open circuit spirometry (Hans Rudolph 2700, Shawnee, KS) and a metabolic cart (Parvo Medics, TrueOne 2400, Sandy, UT). Tests were considered a maximal effort if the participant reached three of the following four criteria: VO_2 plateau, HR within 11 beats per minute (bpm) of age-predicted max, respiratory exchange ratio (RER) $\geq$1.1 and OMNI [64] rating of perceived exertion (RPE) $\geq$ 8 (See Appendix D). Participants received only standardized encouragement (i.e., informing participant as to how much time is left in each stage, encouraging participant to finish the stage, reinforcing the participant's ability to continue). After completion of the GXT, the participant remained in the lab for a 60 minute assessment of BP and subsequently wore an ABPM home for twenty-four hours.

6 and 10 repetition maximum assessment

Participants completed a 6-repetition maximum test on bilateral back squat and bench press and a 10-repetition maximum (RM) protocol was completed for bicep curl, triceps push-down, leg curl, and lat pull-down. These tests followed NSCA testing procedures [65]. Using estimation models to predict an individual's 1 RM is generally accepted as a safer technique than the true assessment of the 1 RM [65]. This study used the 6 RM protocol for multi-joint lifts and 10 RMs for single joint lifts in order to not apply an excessive load on a single joint which may increase risk for injury [65]. Testing procedures are described as follows: bilateral back squat, bench press, leg curl, lat pull-down, bicep curl then triceps push-down.

For maximal testing, the participant warmed up with a light resistance that easily allowed for 8-10/15-20 repetitions. Following this light warm up, the participant rested for 1 minute. The researcher then estimated a load that allowed the participant to perform 7-8/12-14 repetitions with 1 minute rest breaks following. The next lift was the first attempt at either a 6 RM or 10 RM; the investigator estimated a load that required $\leq$ 6/10 repetitions. If the participant performed greater than 6/10 repetitions, the load was increase and another attempt was provided following a 2-4 minute break. If the participant performed $\leq$ 6/10 repetitions, the protocol was considered complete and the estimations were concluded. The goal of the investigation was to reach the participant's 6/10 RM within five attempts in order to avoid fatigue. The weight lifting OMNI rating of perceived exertion was used to evaluate the individual's perceived level of exertion during the testing session (Appendix D). Again, the participant remained in the laboratory for 60 minutes after exercise testing for BP assessment and then sent home with an ABPM to wear for twenty-four hours.

Concurrent cardiovascular - weight training session (CVWT)

Participants completed a concurrent exercise session with aerobic exercise prior to resistance training. The OMNI RPE scale was used to assess perceived exertion during the CV and WT sessions during both CVWT and WTCV protocols. The submaximal aerobic exercise protocol consisted of running for 20 minutes at 65% of the individual's VO_{2peak} which included 5 minute warm up and 5 minute cool down as prescribed by ACSM [6]. Exercise intensity was monitored via open circuit spirometry and oxygen consumption response. Resistance exercise consisted of two sets of six to eight repetitions on bilateral back squat, bench press, leg curl, lat pull-down, bicep curl then triceps push-down (in that order) at 80% of the participant's calculated 1RM. After the completion of the exercise session, the participant remained in the lab for 60 minutes for BP assessment. The participant was informed to continue their activities of daily living with the exemption of any formal exercise.

Concurrent weight training - cardiovascular session (WTCV)

Participants completed a concurrent exercise session that was initiated by WT followed by CV exercise. Submaximal resistance exercise consisted of two sets of six to eight repetitions on bilateral back squat, bench press, leg curl, lat pull-down, bicep curl then triceps push-down at 80% of the participant's calculated 1RM. The submaximal CV protocol consisted of running for 20 minutes at 65% of the individual's VO_{2peak} which included a 5 minute warm up and 5 minute cool down as prescribed by ACSM [6]. Exercise intensity was monitored via open circuit spirometry and oxygen consumption response. Again, the participant remained with the investigator for 60 minutes following exercise for BP assessment and sent home with an ABPM for twenty-four hour BP monitoring.

Statistical analysis

Descriptive data for anthropometric and physiological variables were calculated as mean $\pm$ standard deviation (SD) (Table 1). All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, version 21.0. Armonk, NY., USA). Statistical significance was set at an alpha level of $p \leq 0.05$ for all analyses. A repeated-measures analysis of variance (ANOVA) (conditions x time) was used to determine any differences in SBP at each time interval and differences between conditions for 60 min and twenty-four hour time intervals. Post hoc analyses for the comparisons were analyzed using the Bonferroni post hoc procedure.

CHAPTER 4

RESULTS

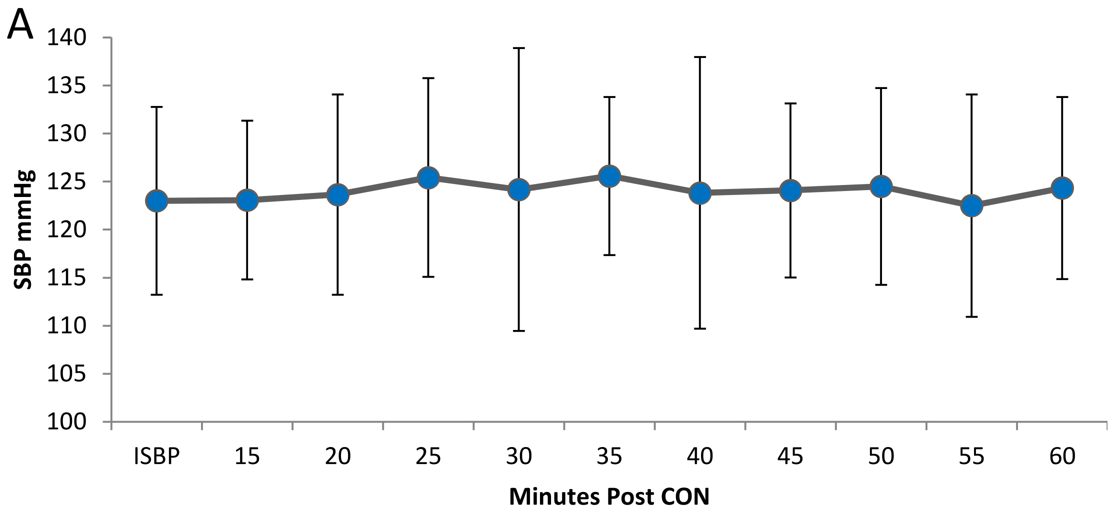
Table 1: Descriptive Statistics of male and female participants

Age	**Height (cm)**	**Mass (kg)**	**Body Composition (%)**	**Resting SBP***
21.69 ± 1.49	171.65 ± 9.62	71.52 ± 13.86	18.4 ± 7.77	124 ± 10.04

*Resting systolic blood pressure from the day one control session.

60 minute PEH following each session

Mauchly's test indicated that the assumption of sphericity had not been violated, $\chi^2(77) = 72.93$, $p = .62$. The results from the repeated measures ANOVA show that there was a significant main effect for time $F(12, 36) = 4.8$, $p = .001$); additionally, the results of a simple effects analysis indicated a significant interaction between time and condition $F(36, 540) = 1.7$, $p = .006$). Post hoc analyses revealed no main effect for condition ($p > .05$). There were no significant magnitudes of PEH during recovery after GXT, WTCV or CVWT (Figure 1).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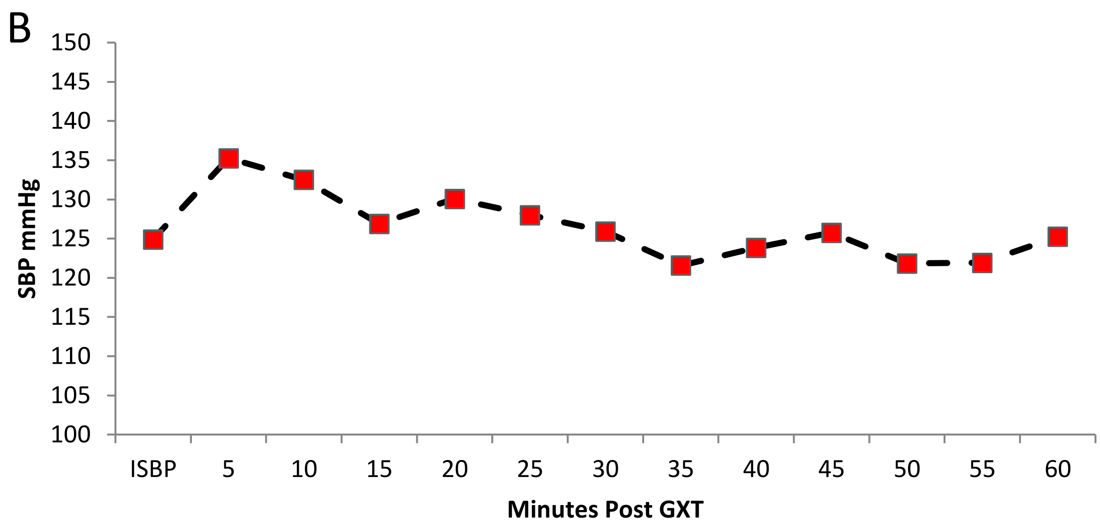
Minutes Post CON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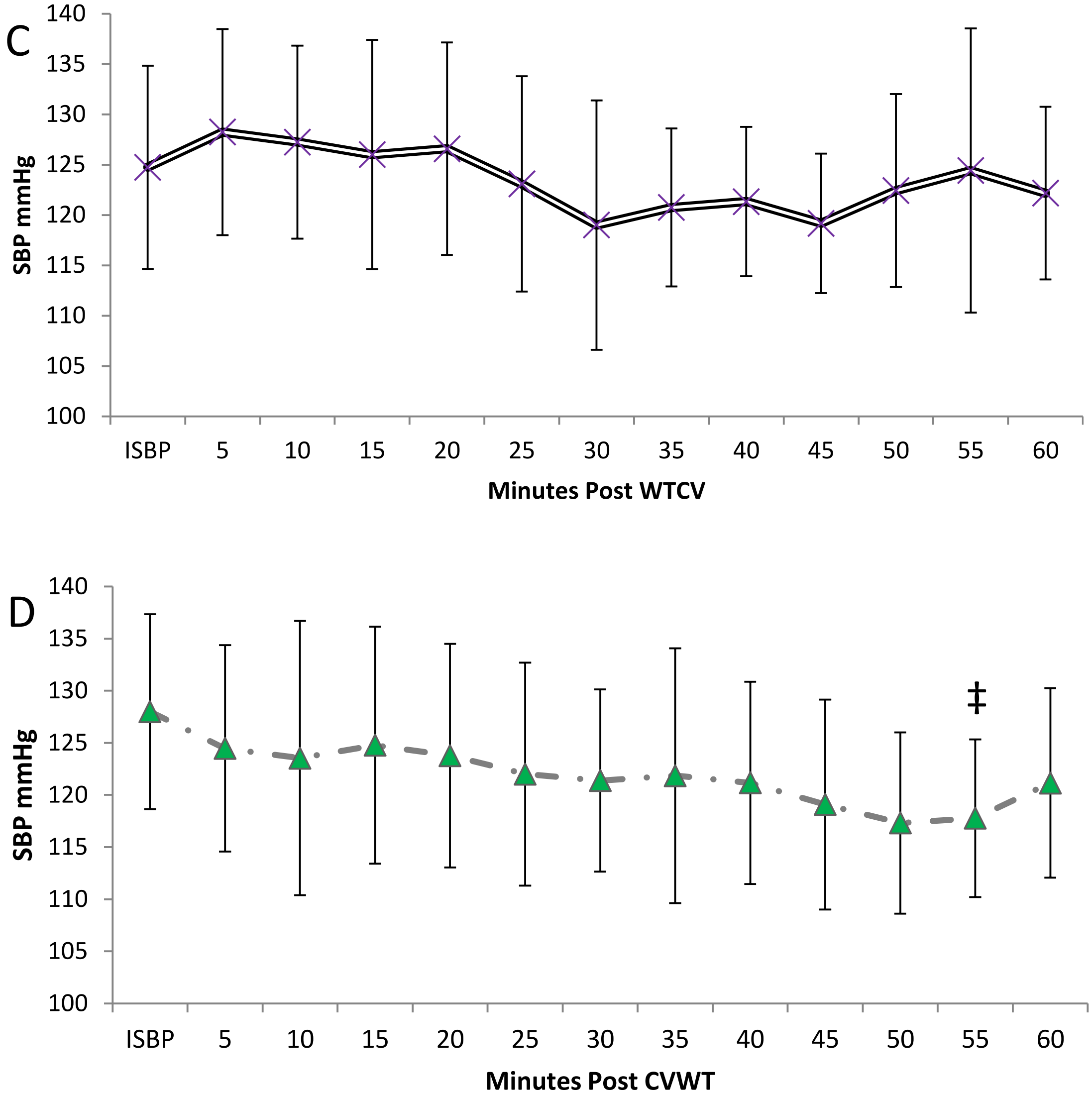
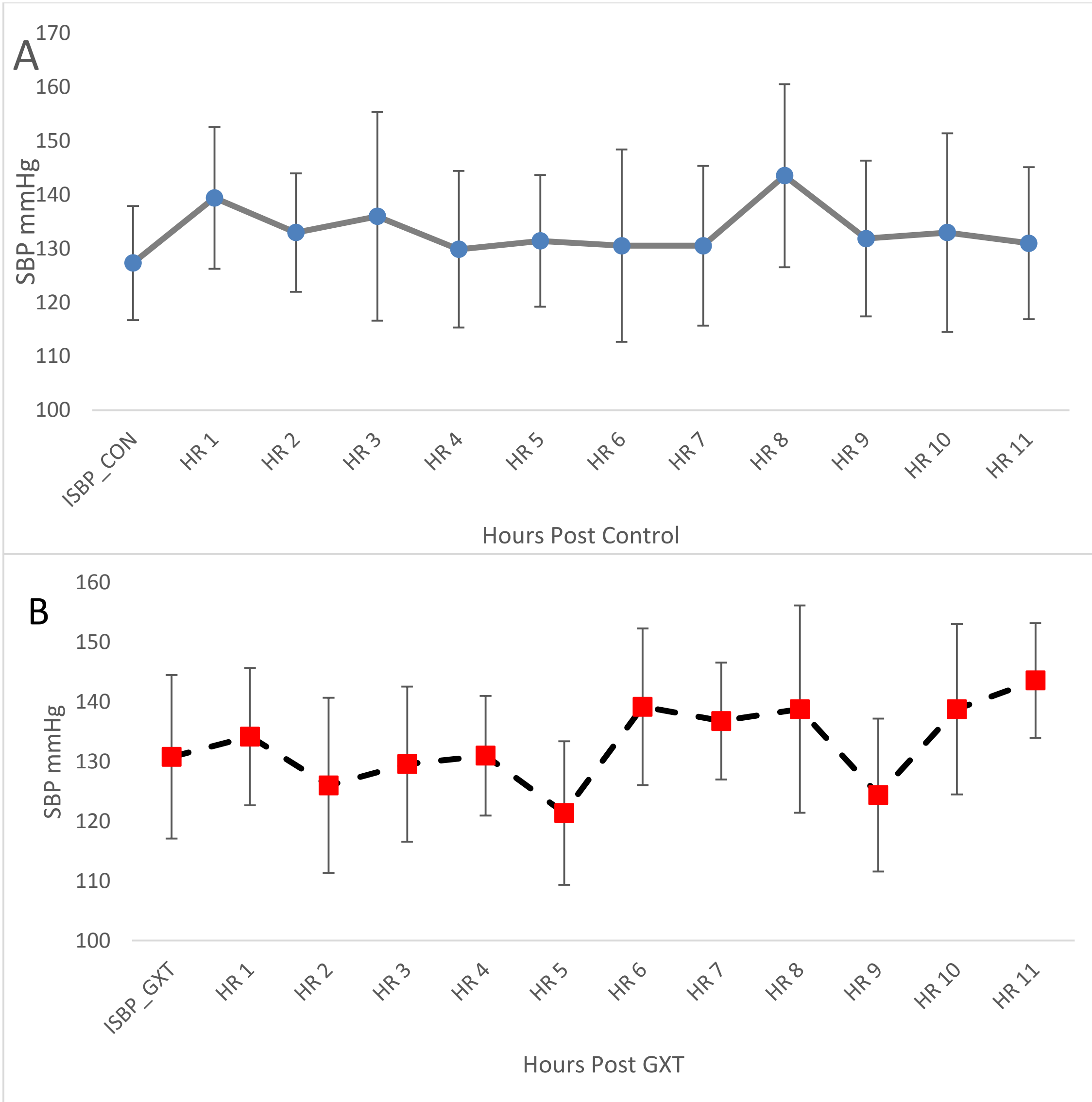


Figure 1: 60 minute recovery systolic blood pressure (SBP). A: control (CON) session; B: graded exercise test (GXT). C: concurrent weight training-cardiovascular (WTCV) session. D: concurrent cardiovascular-weight training (CVWT) session. ‡ CVWT lower than ISBP ($p < .001$). No PEH following CON, GXT, or WTCV.

Systolic blood pressure between conditions: twenty-four hours

Mauchly's test indicated that the assumption of sphericity had not been violated, $\chi^2(65) = 81.16$, $p = .098$. The results show that there was no significant main effect for time $F(11,33) = .043$, $p > .05$); additionally, the results of a simple effects analysis indicated a significant interaction between time and condition $F(33, 308) = 2.02$, $p = .001$). Pairwise comparisons by a Bonferroni adjustment indicate significant differences between ISBP (127.7 $\pm$ 1.7) and hour 8 (134.7 $\pm$ 2.5) ($p = .04$) (Figure 4). No other significant differences were indicated.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SBP mmHg
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HR 8
HR 9
HR 10
HR 11
Hours Post GXT

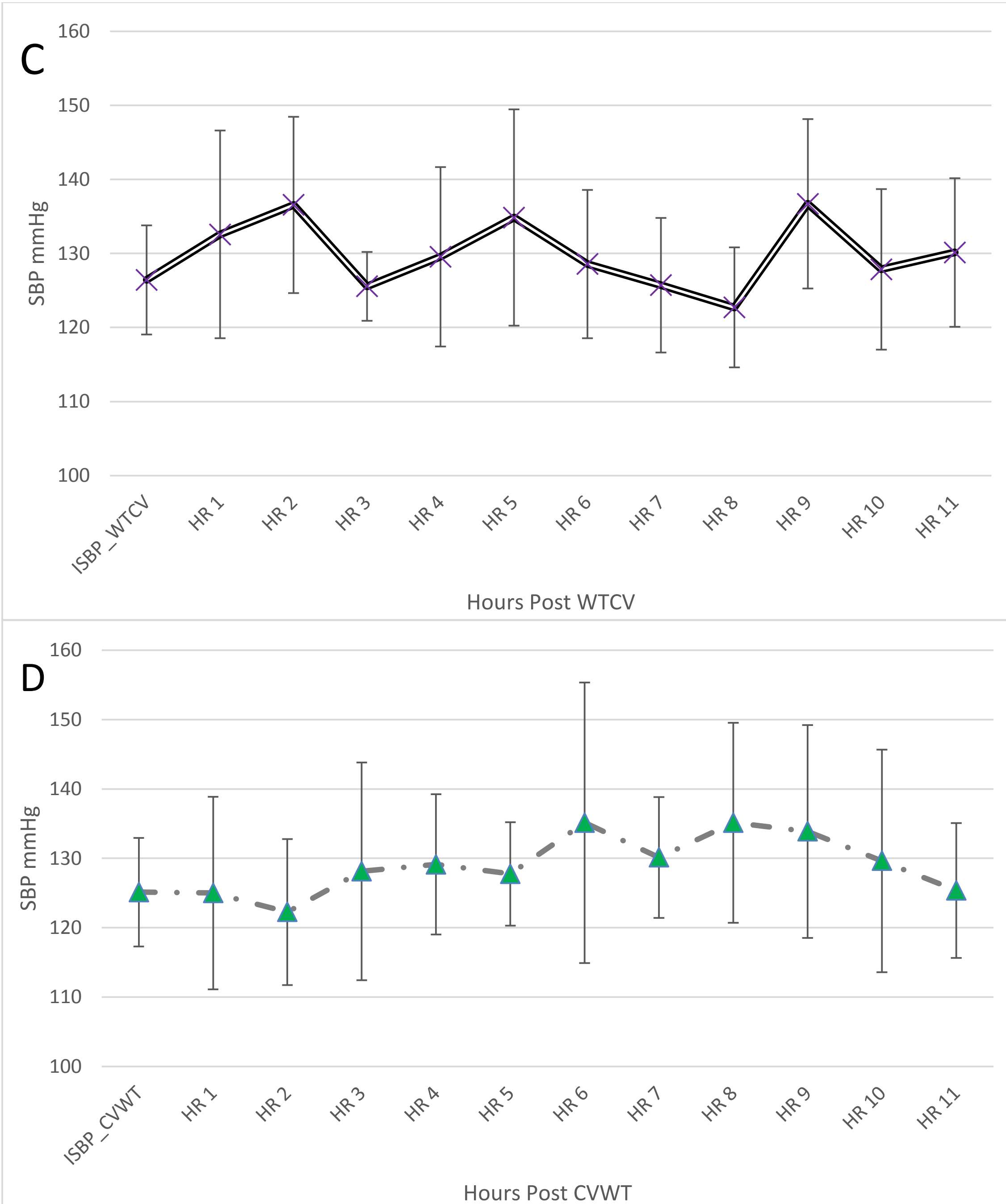


Figure 2: Twenty-four hour assessment of SBP following experimental conditions. No PEH was noted. A: control (CON) session; B: graded exercise test (GXT); C: concurrent weight training-cardiovascular (WTCV) session; D: concurrent cardiovascular-weight training (CVWT) session. No significant PEH was reported per condition.

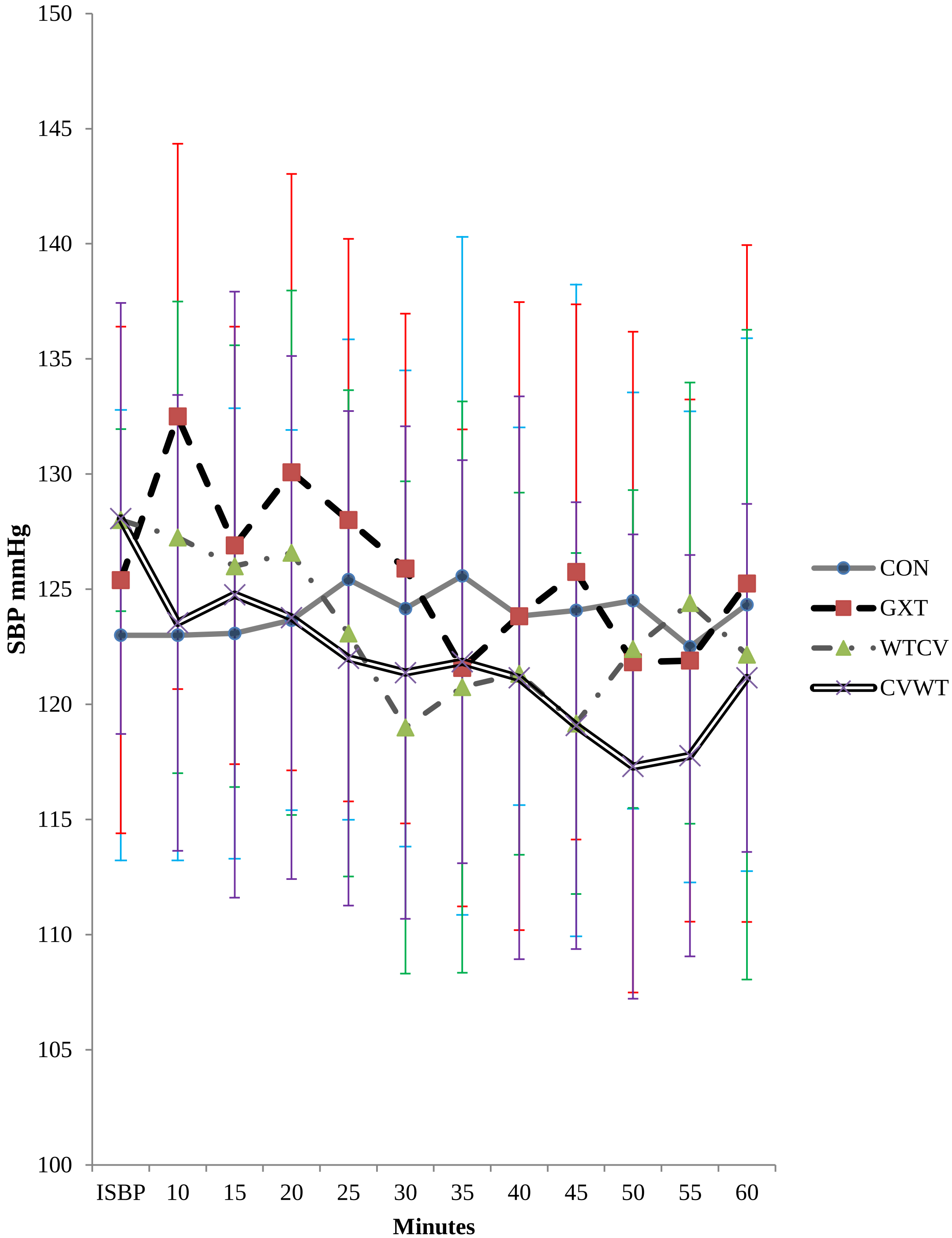


Figure 3: Recovery SBP for 60 minutes post exercise sessions. No significance was noted between conditions. ISBP: Initial systolic blood pressure assessed after 10 minutes of seated rest of each day; CON: control day; GXT: graded exercise test; CVWT: concurrent session ordered cardiovascular/weight training. WTCV: concurrent session ordered weight training/cardiovascular.

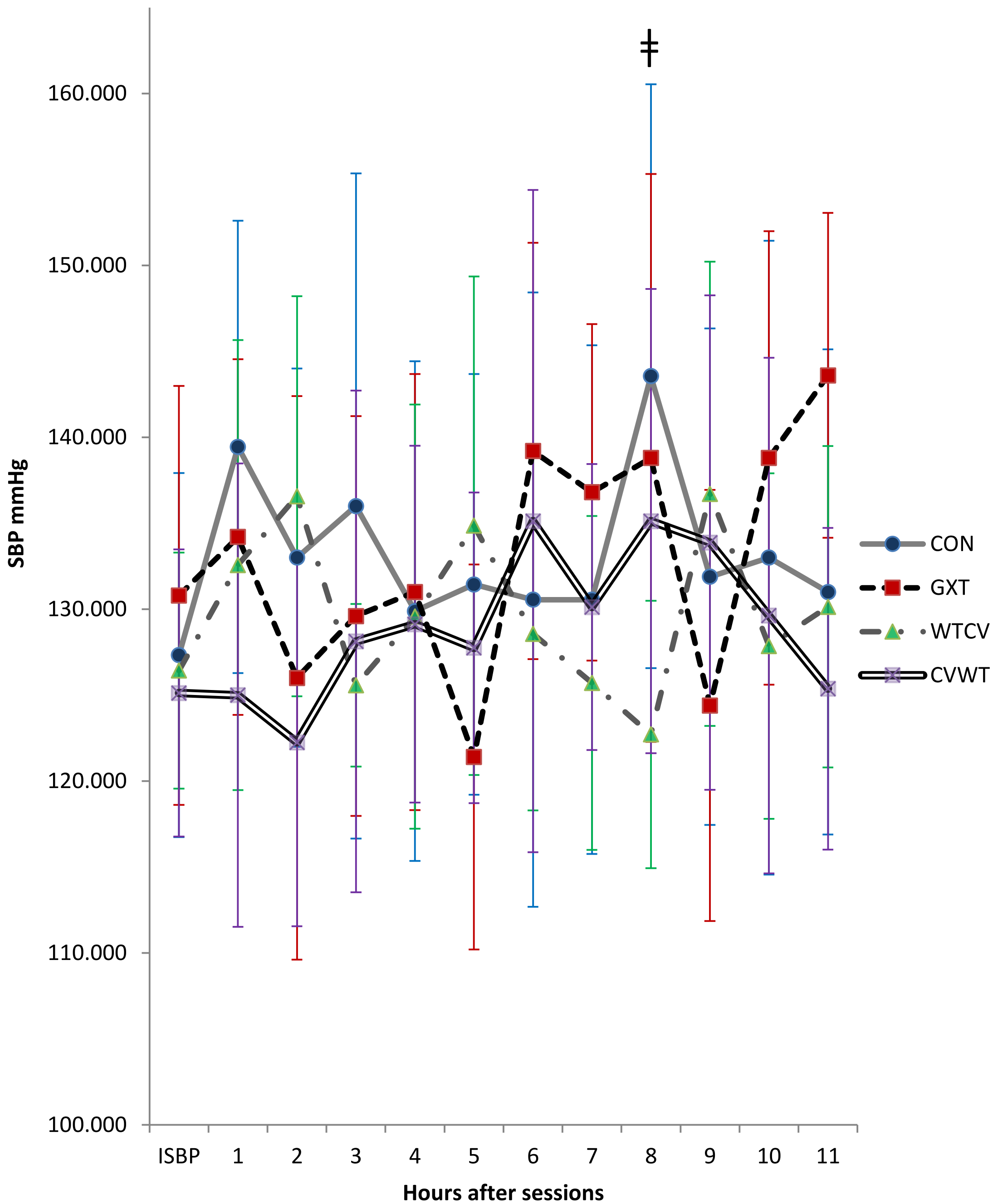


Figure 4: Twenty-four hour SBP; ISBP= Initial systolic blood pressure assessed after 10 minutes of seated rest of each day. ǂ Significance was noted at hour 8 post exercise (*p* = .037). No other differences were noted. ISBP: Initial systolic blood pressure assessed after 10 minutes of seated rest of each day; CON: control day; GXT: graded exercise test; CVWT: concurrent session ordered cardiovascular/weight training. WTCV: concurrent session ordered weight training/cardiovascular.

Twenty-four hour analysis of ADLs

A two-tailed, within subject analysis of variance (ANOVA) was used to determine any differences in activity level using step counts and METs for twenty-four hours; the mean step count and METs for each hour were used in the analysis. There were no main effects for METS or step counts (Figures 5 & 6).

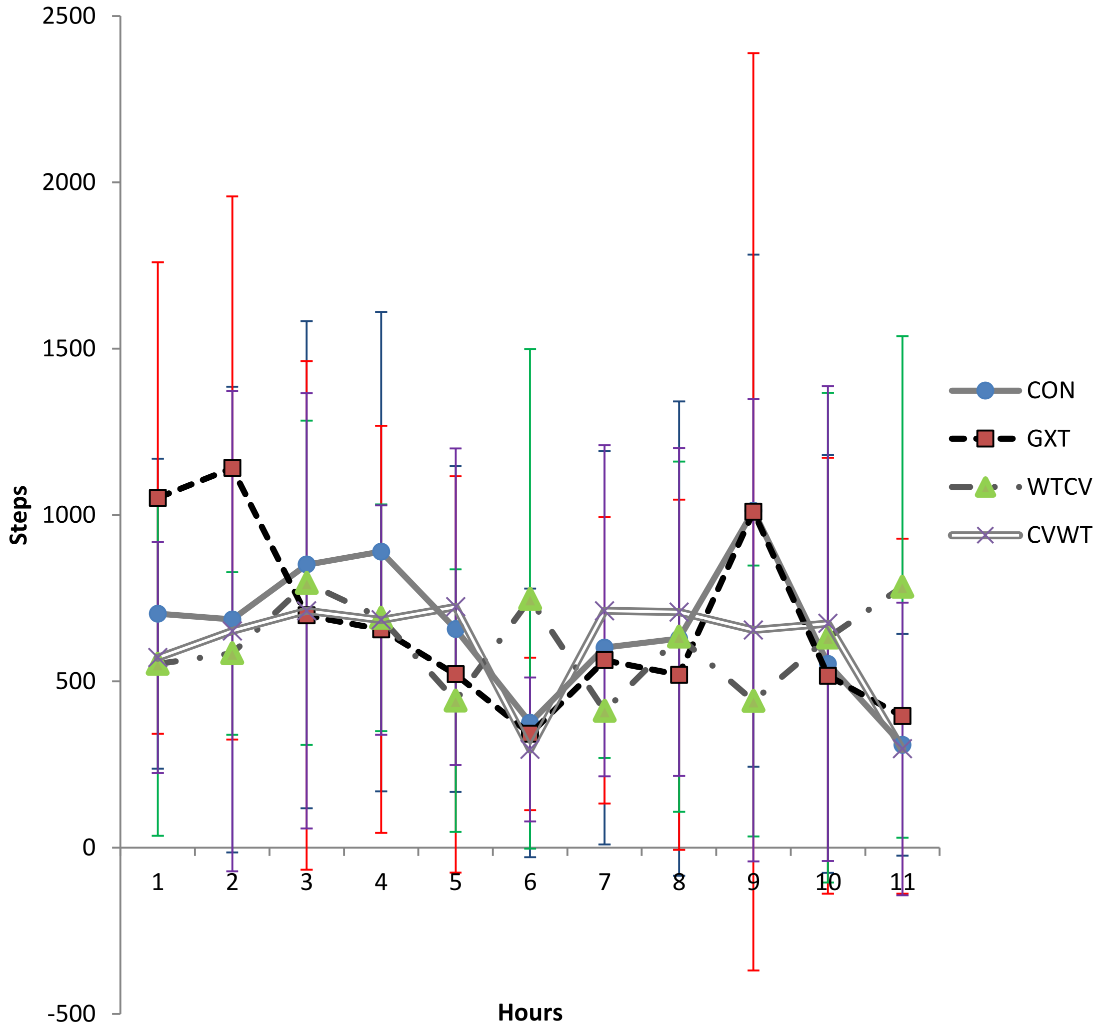


Figure 5: Twenty-four hour step count. CON: control day; GXT: graded exercise test; CVWT: concurrent session ordered cardiovascular/weight training. WTCV: concurrent session ordered weight training/cardiovascular.

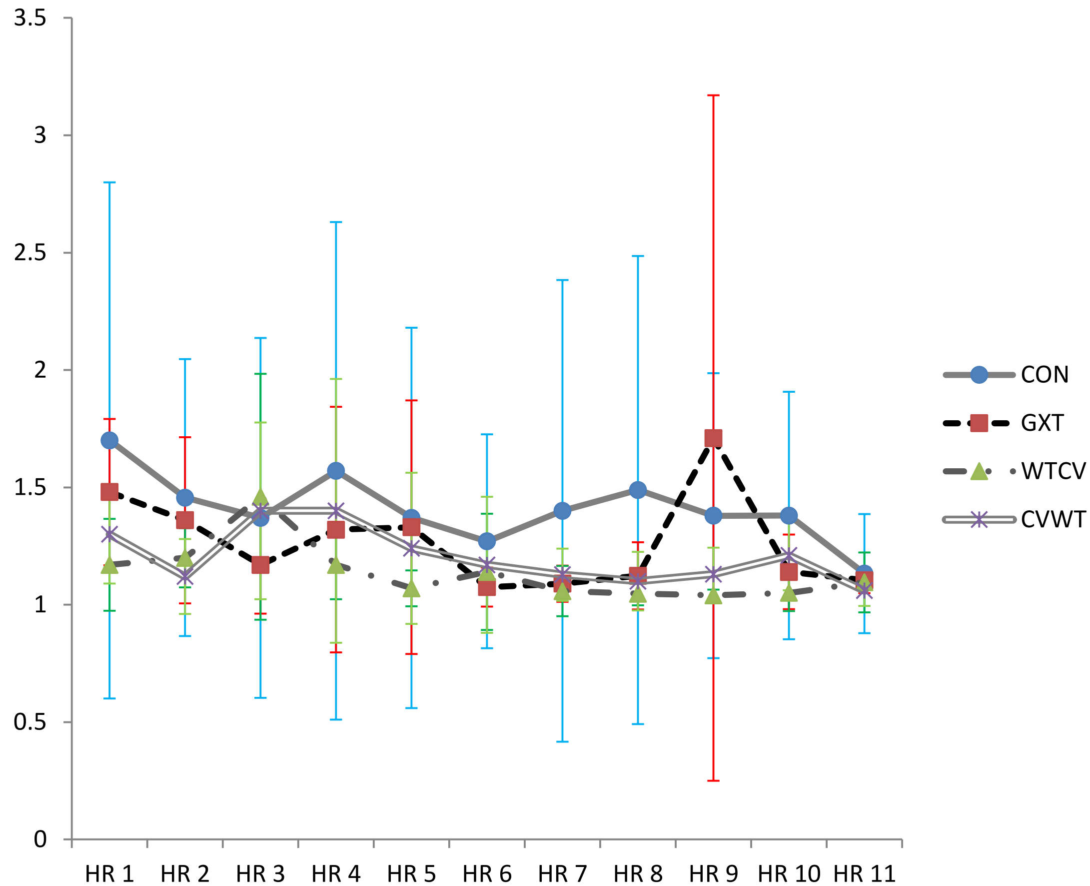


Figure 6: Twenty-four hour METs analysis. HR: hour; no main effects were noted. CON: control day; GXT: graded exercise test; CVWT: concurrent session ordered cardiovascular/weight training. WTCV: concurrent session ordered weight training/cardiovascular.

CHAPTER 5

DISCUSSION

The purpose of this study was to evaluate the immediate systolic blood pressure (SBP) effect when combining two exercise modes on twenty-four hour blood pressure. Furthermore, the investigators evaluated the acute post SBP response when varying the order of cardiovascular and resistance (CVWT, WTCV) exercise to each other, a graded exercise test (GXT), and a non-exercise control day (CON). The main findings from the study were that 1.) There appears to be no differences between a GXT and two concurrent sessions (CVWT & WTCV) in regards to immediate SBP (figure 1); 2.) A significant interaction exists at hour eight post exercise involving CVWT, CON and/or ISBP (figure 2); 3.) There does not seem to be a difference in immediate SBP response following concurrent exercise even when the order of exercise modality is altered (figures 1 & 2). Data indicated that all exercise sessions provoked a modest lowering in SBP when compared to each initial systolic blood pressure; however, the GXT and WTCV sessions failed to elicit a magnitude of PEH significantly different from the ISBP. However, concurrent CVWT provided significant PEH 55 minutes post exercise (figure 1). An additional finding was that there were no significant differences in the magnitude of PEH between concurrent (WTCV and CVWT) sessions throughout the data collection periods (figure 3). There were no significant differences in activity levels between conditions or across time (figures 5 & 6).

It is well accepted that aerobic exercise produces an acute and chronic BP reduction for those who regularly perform cardiovascular exercise. Despite previous literature [12] suggesting that higher intensities of aerobic activity during a graded exercise test (100% VO_{2peak}) would elicit a greater magnitude of PEH compared to lower intensities (40% & 60% VO_{2peak}), data from this study may argue that pairing two exercise modes at moderate intensities will provide equitable SBP response. However, the high intensity exercise compared in this study did not absolutely match the duration of the concurrent CVWT and WTCV sessions. This discrepancy in exercise duration may explain why a maximal intensity exercise did not produce similar magnitudes of PEH to WTCV. Previous literature would explain that longer intervals of moderate-high intensity exercise (40-80 minutes) elicited greater magnitudes and durations of PEH when compared to shorter periods of exercise (10-20 minutes) [34]. Despite the duration variability, a study by Eicher (2010) found significant PEH following a GXT structured much like the present study; however, the investigation previously mentioned recruited a significantly older population with elevated resting SBP [12]. This discrepancy in age and resting blood pressure values may justify why Eicher (2010) witnessed PEH following a GXT and the current study did not.

With the depression following WTCV at hour eight, it may be hypothesized that this order of moderate exercise may elicit greater drops in blood pressure when compared to a maximal bout of aerobic training. The results at present compare to those of previous literature evaluating endothelium-dependent vasodilation [66]; these data suggest that moderate-intensity aerobic exercise (much like concurrent sessions) increased vasodilators (ex. nitric oxide) for longer durations, whereas higher intensities (GXT) increased oxidative stress which may have inhibited comparable PEH [66]. With these data, it may be necessary to evaluate hypothesized vasodilators following concurrent exercise throughout twenty-four hour recovery to determine if a particular vasodilator is active for longer following moderate exercise and not high intensity exercise.

Investigations evaluating the role of exercise mode in eliciting a PEH response often contrast, especially those involving resistance training [3, 7, 19]. Many investigations targeting weight training and PEH have reported PEH following exercise [5, 45, 48, 51, 67] while others report no PEH response [37, 68]. However, no known researchers have attempted to pair aerobic and resistance training, in that order, due to the assumption that resistance training may attenuate the magnitude of PEH [5]. At present, only exercise modes with resistance training presented with modest SBP downward drifts (figure 4) compared to no resistance training sessions during recovery. These findings are comparable to the results from an investigation by MacDonald et. al. (1999) comparing moderate intensity resistance and aerobic exercise sessions; data revealed lower SBP in evening hours following resistance training when compared to the cycling session [46]. Continuing, future research may consider altering the intensities of each modality during concurrent exercise. Keese et. al (2012) reported similar magnitudes of PEH following varying intensities (50%, 65%, and 80%) of aerobic exercise, however, higher intensities of cardiovascular activity led to a longer durations of PEH (response lasted 60 minutes longer after 65% and 80% when compared to 50% VO_2peak). Therefore, it may be beneficial to evaluate if the duration of PEH is extended by increasing the intensity of aerobic exercise in CVWT and WTCV concurrent training.

Although the mechanisms of PEH were not a principal focus of this study, we believe that the magnitude and duration of PEH would not be affected by changing exercise modes even though the central mechanisms responsible for weight training and cardiovascular exercise PEH differ. Researchers suggest that when recovering from aerobic exercise, the drop in arterial BP may be attributed to the combination of reducing sympathetic nerve activity (neural) and local vasodilation mechanisms (vascular) [69]. A potential explanation as to why concurrent WTCV exercise produced greater and longer lasting magnitudes of SBP attenuation may be due to recruiting and activating more muscle mass through two exercise modes. Joyner and Limberg [70] suggest that oxygen delivery to exercising muscles is of great importance to regulating blood pressure. Calbet et. al (2004) argued that the degree of muscle mass recruitment dictated the degree of arterial blood pressure attenuation; an increase in working muscle mass resulted in mean arterial blood pressure decreasing [71].

Regarding resistance training PEH mechanisms, it is purported that these processes are subsequent to a decrease in cardiac output, elicited by a decrease in stroke volume [36]. When this attenuation of stroke volume is not compensated by systemic vascular resistance and then combined with an incomplete rise in heart rate (resulted from the deactivation of parasympathetic pathways with the activation of cardiac sympathetic system) mean arterial blood pressure decreases [36]. The difference in pathways may explain why higher intensities of cardiovascular exercise elicit greater degrees of PEH [69] while lower intensities of weight training provide a greater PEH response compared to higher intensities [36]. However, there are other studies suggesting that higher intensities of resistance exercise are responsible for greater magnitudes of PEH [36].

Future studies should consider concurrent training with higher intensity cardiovascular with varied intensity weight training in order to evaluate if these mechanisms work against each other or synergistically to magnify the PEH response.

These concurrent investigations have utilized moderate intensity aerobic training and whole body resistance training. Future investigations may consider evaluating PEH following concurrent exercise sessions that utilize moderate to high intensity aerobic exercise paired with only lower body resistance sessions and only upper body resistance sessions. Previous literature comparing lower leg ergometry with arm ergometry presented with PEH following both protocols [53]. With the greater threat to homeostasis, upper body exercises may provide a unique PEH response due to the increased threat to resting measures normality.

Twenty-four hour blood pressure investigations reveal extensive BP variability between time of day and exercise conditions. The present data follows the typical diurnal SBP variability explained by Pickering et. al. (1982). Pickering reported that normotensive participants experienced the highest BPs early in the morning and while at work and the lowest at or near sleep intervals [72]. The present study follows this pattern of higher SBP throughout the afternoon and with the lowest SBP reported was in the early morning hours. Although the minimum amount of exercise to obtain blood pressure lowering benefits has yet to be defined, it appears that moderate to high intensity weight training and moderate cardiovascular exercise, in any order, may be effective in lowering SBP beyond resting blood pressure values. Furthermore, it looks as if WTCV fosters the greatest drop in SBP eight hours post exercise when compared to a high intensity GXT, CVWT and a no exercise control. The findings on order of exercise and twenty-four hour assessment after concurrent exercise may be considered novel additions to PEH and concurrent training literature.

To our knowledge, this is the first study to measure twenty-four hour PEH following concurrent exercise while varying the order of exercise modes. Others have measured PEH following WTCV concurrent exercise for 120 minutes [5], but no known studies have measured PEH following a concurrent exercise bout ordered CVWT. Other studies have attempted to measure twenty-four hour PEH following aerobic exercise [35, 38, 47]; these investigations advised participants to only perform typical daily activities, however, none of these studies quantitatively assessed the activity levels (steps and METs) participants engaged in after leaving the laboratory [35, 47]. Therefore, we believe we are the first to attempt to measure the role of ADLs on the continuation of PEH following acute bouts of exercise. Being that there were no differences in activity levels following experimental conditions, it may be argued that the SBP responses throughout the twenty-four hours resulted from the experimental interventions. However, with the results from this study, it may be argued that standard ADLs do not enhance the magnitude of PEH, rather, ADLs may play a role in inhibiting the full effect exercise may play in provoking PEH. With the observation of the discontinuation of SBP decrements immediately upon resuming ADLs, future studies may require participants to remain in a controlled setting following concurrent exercise until SBP has returned to baseline. Future researchers may also consider strategically controlling the intensity of ADLs following concurrent exercise to determine a dose-response in the magnitude of PEH beyond what the initial exercise bout produced. Furthermore, potential avenues for research may involve defining the relationship between diseases that seemingly do not affect the cardiovascular or pulmonary systems (obesity, non-lung cancers, diabetes mellitus, etc.) and PEH response. If PEH is affected by mechanisms outside of the thoracic cavity, data from such investigations may shed light on key processes involved in PEH. Other investigations may consider evaluating the effect concurrent exercise plays in eliciting PEH when prescribed at different times throughout the day. With evidence by Jones et. al. (2008), it may appear that PEH is best fostered by afternoon exercise when compared to morning hours [73]. Being that variability in PEH following aerobic exercise has been demonstrated, it may be advantageous to determine if PEH following concurrent training may be similarly affected.

There are some potential limitations of this study that may have played a role in impacting the blood pressure response following each of the sessions. One limitation is the final amount of blood pressures that were collected over a twenty-four hour period. Due to equipment error and/or lack of compliance of some of the participants, not all of the blood pressures were measured at each time interval. Although the participants performed their specific testing sessions at the same time, the time of day each participant exercised was different. With this variability in time of testing, each participant would wear the cuff for different durations after testing; ex. an 8:00 am participant wore the cuff longer than a 12:00 pm participant the day of testing, but the 12:00 pm participant wore the ABPM longer into the next day than the 8:00 am subject. Furthermore, we believe that a more continuous assessment of BP would have given a more holistic look at PEH response; setting the ABPM to assess BP every fifteen minutes opposed to once an hour may have provided greater insight to the attenuation of BP. Another potential limitation is the possibility for participants to consume caffeine products and the potentially impact the blood pressure response. Continuing, despite quantifying ADLs, the participants in the study were exposed to extraneous psychosocial stressors (tests, quizzes, work, etc.) that might have affected their BP, yet was unmeasurable through the accelerometer process. A study by Räikkönen et. al. (1999) quantified the negative cardiovascular effects (elevated SBP) that stressors such as driving, social interaction, anxiety and location (work vs. home) have on ambulatory blood pressure [74]. These stressors may be the underlying reason why ambulatory blood pressure following the experimental sessions were higher than the ISBP until hour nine; this time frame represents when individuals were in class, receiving feedback on tests or assignments, driving to jobs and doing homework. Future investigations should consider either controlling the environment participants return to following experimental sessions or having subjects keep a diary qualitatively evaluating the personal experiences exposures after each session.

The popularity of concurrent training is ever growing; recent literature went viral after being publicized by the Washington Post. Presented by Schumann et. al. (2014), the prevalent article suggests that individuals performing concurrent exercise while counterbalancing the modalities did not depress health fitness benefits based (lean body mass and fitness) based on the order of modality prescription [75]. With concurrent exercise growing in popularity and the recent discovery of its role in health fitness, it is important to determine the cardiovascular related benefits this type of exercise may provide. As such, this study provides insight into how SBP will acutely respond to concurrent exercise, with counterbalanced modalities, when ADLs are limited.

In conclusion, this investigation may suggest that physical activity structured with multiple exercise modes will elicit an acute diminution of SBP. Disputing past theories on PEH and concurrent training [5], this study would suggest that the order of exercise may not affect the attenuation of BP following exercise. Therefore, individuals who prefer concurrent training should not be limited to a specific order of exercise to receive acute decrements in SBP from said exercise. With inconsistent differences in the magnitudes of twenty-four hour SBP following the experimental conditions, it may be argued that exercise mode, intensity or order of exercise modes affect ambulatory BP in variable ways; however, it does not appear that any particular mode undermined potential acute CVD benefits of exercise. This study contributes to current PEH literature by way of admonishing the claim that weight training should not be performed after cardiovascular exercise. Furthermore, this study was the first of its kind to measure SBP for a twenty-four hour period following concurrent exercise. Lastly, the acknowledgment and description of study limitations will allow for future investigators to control more for extraneous variables. Although PEH was not elicited in this investigation there is something to be said about a blood pressure that remains relatively steady throughout the day despite the activities of daily living and the normal stressors of the day. Though significant PEH was not noted from this investigation, there are evident downward slopes of SBP following concurrent sessions. Any duration and magnitude of lowered blood pressure should be considered a success for cardiovascular health. With this, this study revealed that concurrent exercise may foster beneficial cardiovascular responses (lowered SBP) when activities of daily living are controlled for in a laboratory setting and continuing into ambulatory settings.

APPENDIX A

INFORMED CONSENT

WKU

Exercise Science

Department of Kinesiology, Recreation & Sport

Informed Consent Document

Project Title: twenty-four Hour Post Exercise Hypotension Following Concurrent Aerobic and Resistance Exercise.

Investigator: Whitley Stone, Dept. of Kinesiology, Recreation and Sport

whitley.stone761@topper.wku.edu (865)719-8557

You are being asked to participate in a project conducted through Western Kentucky University. The University requires that you give your signed agreement to participate in this project.

The investigator will explain to you in detail the purpose of the project, the procedures to be used, and the potential benefits and possible risks of participation. You may ask him/her any questions you have to help you understand the project. A basic explanation of the project is written below. Please read this explanation and discuss with the researcher any questions you may have.

If you then decide to participate in the project, please sign on the last page of this form in the presence of the person who explained the project to you. You should be given a copy of this form to keep.

1. **Nature and Purpose of the Project:**

Physical activity has shown to short and long term decreases blood pressure, but the exercise prescription that best stimulates this response remains clear. Many investigations have seen a drop in blood pressure after exercise, termed post exercise hypotension, following cardiovascular and resistance training. Few studies have attempted to measure this drop in blood pressure after concurrent exercise. Concurrent training is the combination of aerobic and resistance exercise within a single day. Some researchers suggest that resistance exercise following aerobic training will undermine the potential drop in blood pressure from aerobic exercise. Therefore, the purpose of this study is to measure post exercise hypotension following a bout of concurrent aerobic-resistance exercise and a bout of concurrent resistance-aerobic exercise. Twenty-four hour blood pressure following exercise will be measured in order to determine if resistance exercise will diminish the magnitude of PEH.

2. **Explanation of Procedures:**

You will be asked to come to the Exercise Physiology Laboratory at Western Kentucky University on five occasions for approximately 60 to 90 minutes. Prior to performing the testing procedures on day one, the investigators will measure your: body composition, blood pressure, weight, & height. To minimize risks when performing the testing procedures, you will be asked to complete a Physical Activity Readiness Questionnaire (PAR-Q) and a medical history form which asks questions about your current health status. If you are classified as *moderate risk* according to the American College of Sports Medicine risk stratification guidelines, you will be excluded from participation in this research study. In addition, if you have an orthopedic (muscle or bone), cardiovascular (heart), and/or metabolic disease (i.e. coronary artery disease (heart disease), prior myocardial infarction (heart attack), peripheral vascular disease (blockages in legs), chronic obstructive pulmonary disease (COPD-lung disease), and diabetes mellitus (high/low blood sugar) you will be excluded from participation in this research study.

During each of the study sessions you will perform a series of tests based on your assigned testing order. You will be randomly assigned to the order in which you will perform your testing sessions. Session A will consist of a no exercise control period in which you will sit quietly for 60 minutes. Session B will serve to measure your 6 and 10 repetition maximum (RM). Session C consists of measuring your maximal aerobic capacity (VO_{2max}) by using a treadmill graded exercise test. Session D is comprised of you starting with cycling at a submaximal effort (65% VO_2max) for 30 minutes; after the aerobic exercise, you will perform 2 sets of 6-8 repetitions at 80% of your estimated 1RM on 6 different muscle groups (bilateral back squat and bench press

bicep curl, triceps push-down, leg curl, and lat pull-down). Once all exercises are complete, you will be asked to remain in the lab for 60 minutes to allow for the measurement of your post exercise blood pressure. Following the rest period, you will be fitted with an accelerometer and ambulatory blood pressure monitor that will remain on your arm and wrist for twenty-four hours. The blood pressure monitor will measure your blood pressure 3 times per hour until 11pm and then 1 time per hour throughout the night.

You will return the ambulatory blood pressure monitor and accelerometer to the investigator the following day. Session E is very similar to Session D; during this session, you will perform the resistance exercises first and the aerobic exercise second. All exercise intensities and durations are equal in Session D and Session E. You will wear the accelerometer and ambulatory blood pressure monitor home and return both to the investigator the following day.

Below is a brief description of each of the testing procedures. Detailed instructions will be provided by the investigators prior to you performing each of the procedures. There will be a minimum of 5 minutes of rest between the assessment of different muscle groups.

1.) *Height* and *weight* will be measured using a standard digital scale and stadiometer.

2.) *Body composition* will be measured using skinfold calipers. The investigator will access sites on your chest, belly, waist, upper arm and pinch each site using the calipers.

3.) A heart rate monitor will be placed around your chest and secured in place with an elastic strap to determine your heart rate when exercising.

4.) *6 repetitions maximum*

- *Bench press*: Lying on a bench with a spotter above the bar, you will warm up by performing repetitions with a load that allows 10-15 repetitions. After a one minute rest you will be given a weight that will allow 8-10 repetitions. After a two minute rest you will be given a load that will allow 7-8 repetitions. After a four minute rest you will attempt a 6 repetitions maximal lift.
- *Bilateral back squat.* Standing in a squat rack, with spotters on both side of the bar, you will warm up by performing repetitions with a load that allows 10-15 repetitions. After a one minute rest you will be given a weight that will allow 8-10 repetitions. After a two minute rest you will be given a load that will allow 7-8 repetitions. After a four minute rest you will attempt a 6 repetitions maximal lift.
- *Leg extension*: sitting on the Paramount leg station, you will warm up by performing repetitions with a load that allows 15-20 repetitions. After a one minute rest you will be given a weight that will allow 13-15 repetitions. After a two minute rest you will be given a load that will allow 11-12 repetitions. After a four minute rest you will attempt a 10 repetitions maximal lift.
- *Lat pull-down*: sitting on the Paramount upper body station, you will warm up by performing repetitions with a load that allows 15-20 repetitions. After a one minute rest you will be given a weight that will allow 13-15 repetitions. After a two minute rest you will be given a load that will allow 11-12 repetitions. After a four minute rest you will attempt a 10 repetitions maximal lift.

- *Leg curl:* sitting on the Paramount leg station, you will warm up by performing repetitions with a load that allows 15-20 repetitions. After a one minute rest you will be given a weight that will allow 13-15 repetitions. After a two minute rest you will be given a load that will allow 11-12 repetitions. After a four minute rest you will attempt a 10 repetitions maximal lift.
- *Triceps push-down:* sitting on the Paramount upper body station, you will warm up by performing repetitions with a load that allows 15-20 repetitions. After a one minute rest you will be given a weight that will allow 13-15 repetitions. After a two minute rest you will be given a load that will allow 11-12 repetitions. After a four minute rest you will attempt a 10 repetitions maximal lift.

5.) *Graded exercise test*: You will be asked to walk and run on a treadmill while wearing a mask to measure your oxygen consumption. The speed and grade start at 1.7 MPH and 10% grade and increases in speed and grade every three minutes. You will be asked to give a maximal effort.

3. **Discomfort and Risks:**

You may experience discomfort wearing the heart rate monitor, accelerometer and ambulatory blood pressure monitor; these devices may cause redness, irritation, and chafing. Ambulatory blood pressure assessment may cause interrupted sleep during the night time hourly measurement.

4. **Benefits:**

You have no benefit to participation. You will learn how they rank in body composition, strength, and aerobic capacity compared to their percentile norm based on gender and age. To thank you for your time and participation, you will be paid $30 after the completion of all sessions.

5. **Confidentiality:**

Any information about you obtained from this research will be kept confidential. All records related to your involvement in this research study will be stored in a locked file cabinet as well as a password-protected computer. Your identity on these records will be indicated by a case number rather than by your name, and the information linking these case numbers with your identity will be kept separate from the research records. You will not be identified by name in any publication of the research results.

6. **Refusal/Withdrawal:**

Refusal to participate in this study will have no effect on any future services you may be entitled to from the University. Anyone who agrees to participate in this study is free to withdraw from the study at any time with no penalty.

You understand also that it is not possible to identify all potential risks in an experimental procedure, and you believe that reasonable safeguards have been taken to minimize both the known and potential but unknown risks.

____ _______________

Signature of Participant Date

____ _______________

Witness Date

THE DATED APPROVAL ON THIS CONSENT FORM INDICATES THAT

THIS PROJECT HAS BEEN REVIEWED AND APPROVED BY

THE WESTERN KENTUCKY UNIVERSITY INSTITUTIONAL REVIEW BOARD

Paul Mooney, Human Protections Administrator

TELEPHONE: (270) 745-2129

APPENDIX B

MEDICAL HISTORY

Exercise Physiology Laboratory

MEDICAL HISTORY

Now I am going to ask you a few questions to determine if your health status …

	Yes	No
History of heart problems, chest pain, or stroke?		
Increased blood pressure?		
Any chronic illness or condition?		
Difficulty with physical exercise?		
Advice from a physician not to exercise?		
Recent surgery? (Last 12 months)		
Pregnancy? (Now or within the last 3 months)		
History of breathing or lung problems?		
Muscle, joint, back disorder, or any previous injury still affecting you?		
Diabetes or thyroid conditions?		
Cigarette smoking habit?		
Increased blood cholesterol?		
History of heart problems in your immediate family?		
Hernia or any condition that may be aggravated by lifting weights?		
Do you have any condition limiting your movement?		
Are you aware of being allergic to any drugs or insect bites?		
Do you have asthma?		
Do you have epilepsy, convulsions, or seizures of any kind?		
Do you follow any specific diet?		

Please explain in detail any “YES” answers:

Family History

Has any member of you family had any of those listed above

APPENDIX C

PAR-Q

Participant ID:________

Exercise Physiology Laboratory

Physical Activity Readiness Questionnaire (PAR-Q)

Now I am going to ask you a few questions to determine if you are eligible to participate in the study.

1 Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?

No ___ Yes ___ If yes, specify: ______________________________

1 Do you feel pain in your chest when you do physical activity?

No ___ Yes ___ If yes, specify: ______________________________

1 In the past month, have you had chest pain when you were not doing physical activity?

No ___ Yes ___ If yes, specify: ______________________________

1 Do you lose your balance because of dizziness or do you ever lose consciousness?

No ___ Yes ___ If yes, specify: ______________________________

1 Do you have a bone or joint problem that could be made worse by a change in your physical activity?

No ___ Yes ___ If yes, specify: ______________________________

1 Is your doctor currently prescribing drugs (for example, water pills) for a blood pressure or heart condition?

No ___ Yes ___ If yes, specify: ______________________________

1 Do you know of any other reason why you should not do physical activity?

No ___ Yes ___ If yes, specify: ______________________________

Please provide accurate information for all requested items. Ask a staff member to assist you if you need clarification of any item.

Write a **Y** for all statements that are true, write a **N** for all statements that are false, and write a **U** for all statements that are unknown.

Cardiovascular Risk Factors

_____ You have a first-degree relative who had a heart attack or coronary revascularization **or** sudden death before age 55 (father or brother) **or** age 65 (mother or sister)

_____ You smoke cigarettes **or** you quit smoking cigarettes within the last 6 months.

_____ Your systolic blood pressure is $\geq$ 140 **or** your diastolic blood pressure is $\geq$ 90 mmHg **or** you take blood pressure medication.

_____ You are sedentary (i.e. you get less than 30 minutes/day of moderate intensity physical activity on most days and you do not participate in a regular exercise program).

Symptoms

_____ You experience pain or discomfort in the chest, neck, or arms.

_____ You experience shortness of breath at rest or with mild exertion.

_____ You experience dizziness or have had episodes of blackouts.

_____ You have swelling of the ankles

_____ You experience shortness of breath with change of posture or while sleeping

_____ You experience episodes of rapid heartbeats or skipped heart beats.

_____ You experience pain or cramping sensations in your legs when walking.

_____ You experience fatigue or shortness of breath with unusual activities.

Medical History

You have or have had:

_____ Heart murmur _____ heart attack

_____ heart surgery _____ a lung disease

_____ a metabolic disease (diabetes, thyroid disorder, kidney or liver disease)

List all other notable health problems, injuries, or conditions

____

____

List names/doses/frequency of all medications taken (if not taking any medications, write "NONE")

____

____

Staff Comments

____

____

APPENDIX D

OMNI SCALE

Figure # 1. OMNI Walk/Run Rating of Perceived Exertion

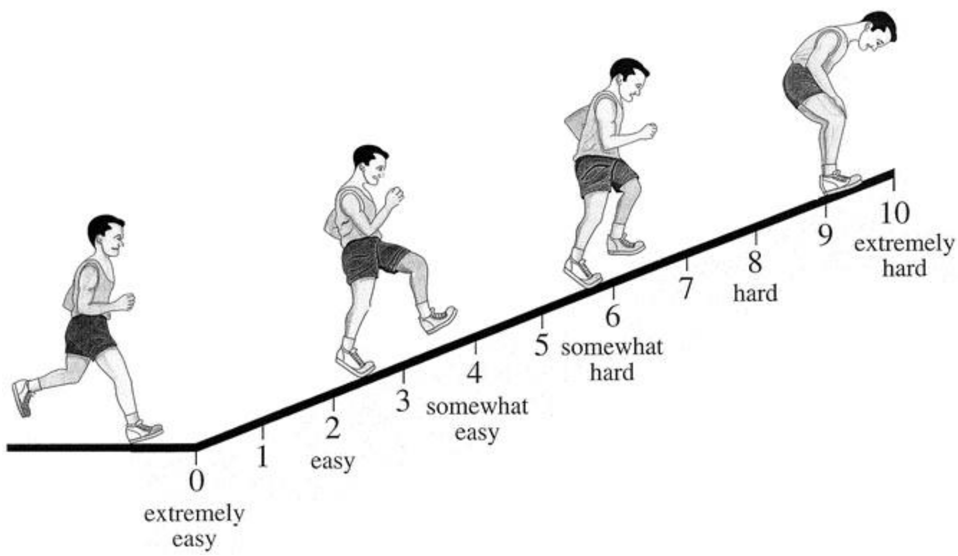
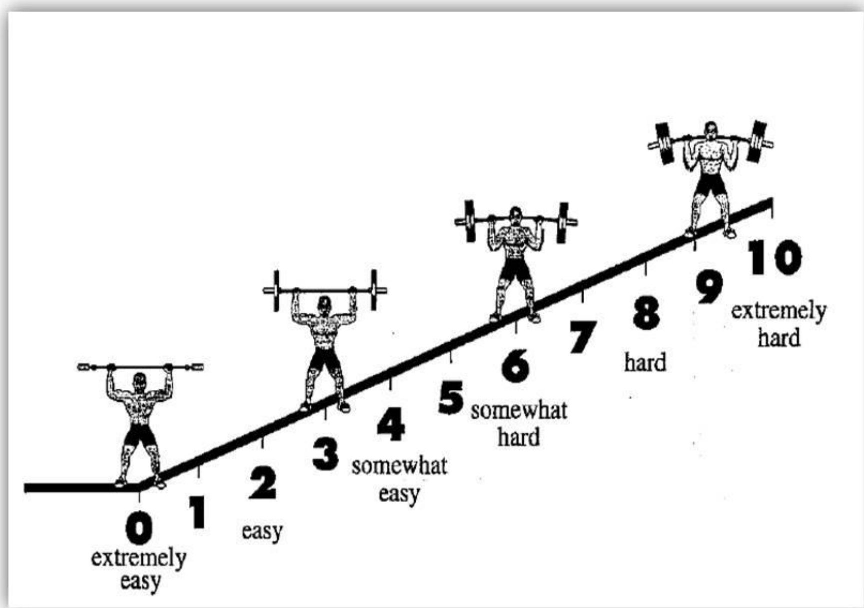


Figure # 2 OMNI Weight Lifting Rating of Perceived Exertion



APPENDIX E

PHYSICAL ACTIVITY EXPERIENCE

Physical Activity Experience

Do you currently participate in regular physical activity? YES or NO

If yes, please describe in detail what activity you participate in (ex: weight train 3 days a week for 60 min):

____
____
____

In the past, did you participate in regular physical activity? YES or NO

If yes, please describe in detail the activity in which you participated in (same as above, please provide year this activity started and when you discontinued this activity:

____
____
____

Do you participate in intramural activities? YES or NO

If yes, please describe the activity and how long you have participated in this activity:

____
____
____

If you have not been regularly active, please describe how long you have been sedentary (less than 3 days of 30 minutes or more of exercise):

____
____
____

APPENDIX F

Table 1

Session A:	**Session B:**	**Session C:**	**Session D:**	**Session E:**
No Exercise Control	**Graded Exercise Test**	**6 and 10 Repetition Maximum**	**Concurrent Aerobic/ Resistance (CVWT)**	**Concurrent Resistance/ Aerobic (WTCV)**

*All participants' day 1 will be Session A. Sessions B and C will be counterbalanced for participants' days 2 and 3. Sessions D and E will be counterbalanced for participants' days 4 and 5. Each testing session will be separated by 48-72 hours.

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